

Astronomy in secondary school: using a guidebook in the teaching of Chemistry

Astronomia no ensino médio: elaboração de uma cartilha educativa para o ensino de Química

Astronomía en la educación secundaria: desarrollo de una cartilla didáctica para la enseñanza de la Química

Received: 09/11/2022 | Revised: 09/25/2022 | Accepted: 09/27/2022 | Published: 10/04/2022

Ívina Thayná Miranda Trindade

ORCID: <https://orcid.org/0000-0002-2744-9583>
Universidade Federal do Amazonas, Brazil
E-mail: ivinamiranda.17@gmail.com

Ana Cláudia Batista de Oliveira

ORCID: <https://orcid.org/0000-0003-2521-1966>
Universidade Federal do Amazonas, Brazil
E-mail: anaclaudia135oliveira@gmail.com

Brenda Cibelle Protazio dos Santos

ORCID: <https://orcid.org/0000-0002-3287-2765>
Universidade Federal do Amazonas, Brazil
E-mail: cibel_ly@outlook.com

Dâmila Ferreira Costa

ORCID: <https://orcid.org/0000-0003-3488-2489>
Universidade Federal do Amazonas, Brazil
E-mail: damilacosta18@gmail.com

Thalison de Castro

ORCID: <https://orcid.org/0000-0002-8770-761X>
Universidade Federal do Amazonas, Brazil
E-mail: thalisoncastro@gmail.com

Ricardo Pinheiro Torres

ORCID: <https://orcid.org/0000-0002-6303-4211>
Universidade Federal do Amazonas, Brazil
E-mail: redtorres30.rt@gmail.com

Elson Almeida de Souza

ORCID: <https://orcid.org/0000-0002-7076-8504>
Universidade Federal do Amazonas, Brazil
E-mail: eamrosa@ufam.edu.br

Geone Maia Correa

ORCID: <https://orcid.org/0000-0002-9458-8305>
Universidade Federal do Amazonas, Brazil
E-mail: geonemaia@ufam.edu.br

Jean Michel dos Santos Menezes

ORCID: <https://orcid.org/0000-0003-2769-1887>
Universidade Federal do Amazonas, Brazil
E-mail: jeanmichelsm@ufam.edu.br

Dominique Fernandes de Moura do Carmo

ORCID: <https://orcid.org/0000-0002-8835-1619>
Universidade Federal do Amazonas, Brazil
E-mail: dominiquefmc@ufam.edu.br

Abstract

In view of the challenges encountered in education, especially those posed by the ongoing SARS-CoV-2 pandemic and resulting school shutdowns, teachers and school administrators have looked for alternatives to conventional face-to-face teaching methods. This study aimed at advancing the teaching of chemistry by means of a contextualized and interdisciplinary approach integrating the curriculum topic “Solar System” to general chemistry concepts and theories. To this end, online and face-to-face classes, supported by a guidebook, were conducted about the subject matter in question at a public secondary school in Itacoatiara, AM, Brazil. The participating students responded to two questionnaires, an exploratory questionnaire and an evaluation questionnaire before and after the intervention, respectively. The guidebook was made available to participants both face-to-face and virtually (Google Classroom). The results suggest that the use of contextualization in classes about the solar system was capable of motivating the participants to learn chemistry concepts and theories. In addition, the results indicate that the students would like to experience other chemistry teaching methods that promote learning beyond the classroom.

Keywords: Chemical composition; Solar system; Teaching; Alternative methods.

Resumo

Considerando os problemas enfrentados atualmente no Ensino, ocasionado, principalmente, pelo período pandêmico através da disseminação do vírus SARS-CoV-2 e a consequente paralisação das aulas presenciais, busca-se alternativas que possam contribuir para uma melhoria no processo de Ensino e Aprendizagem. Assim, este trabalho foi elaborado com o objetivo de promover o Ensino de química através de uma abordagem contextualizada e interdisciplinar associando o tema “Sistema solar” com assuntos de Química Geral. Para isto foram realizadas, inicialmente, aulas teóricas (presencial e remota) sobre os assuntos propostos em uma turma do ensino médio de uma escola estadual localizada no Município de Itacoatiara/Amazonas, bem como a aplicação de dois questionários, um de protocolo de entrevista e outro questionário avaliativo. Em seguida foi feita a elaboração de uma cartilha com os conteúdos discutidos, disponibilizada em sala de aula e na sala virtual do Google Classroom. A partir dos resultados constatou-se que o uso de aulas teóricas contextualizadas com o assunto sobre o sistema solar contribui para a motivação do estudo de química, uma vez foram relacionadas com temáticas cotidianas. O estudo também mostrou que os alunos gostariam de utilizar outras metodologias na disciplina de química, oportunizando assim novas formas de aprender para além da sala de aula.

Palavras-chave: Composição; Sistema solar; Ensino; Metodologias alternativas.

Resumen

Considerando los problemas que enfrenta actualmente la Enseñanza, ocasionados principalmente por el período de pandemia por la propagación del virus SARS-CoV-2 y la consecuente paralización de las clases presenciales, se buscan alternativas que puedan contribuir a una mejora en la Enseñanza y Proceso de aprendizaje. Así, este trabajo fue elaborado con el objetivo de promover la Enseñanza de la Química a través de un abordaje contextualizado e interdisciplinario asociando el tema "Sistema Solar" con asignaturas de Química General. Para ello, inicialmente se realizaron clases teóricas (presenciales y a distancia) sobre los temas propuestos en una clase de secundaria de una escuela pública situado en el Municipio de Itacoatiara/Amazonas, así como la aplicación de dos cuestionarios, uno de tipo entrevista protocolo y otro cuestionario evaluativo. Luego, se elaboró una cartilla con los contenidos tratados, puesto a disposición en el aula y en la sala virtual de Google Classroom. A partir de los resultados se encontró que el uso de clases teóricas contextualizadas con el tema del sistema solar contribuye a la motivación del estudio de la química, ya que se relacionaron con temas cotidianos. El estudio también mostró que a los estudiantes les gustaría utilizar otras metodologías en la disciplina de la química, proporcionando así nuevas formas de aprendizaje más allá del aula.

Palabras clave: Composición; Sistema solar; Enseñanza; Metodologías alternativas.

1. Introduction

Contextualized teaching has now become indispensable in order to counter conventional ways of teaching curriculum contents, in which theories and concepts were presented to students in a fragmented and isolated manner, distant from the real-world context of scientific, social, and educational production (Kato & Kawasaki, 2011). Contextualization is, thus, a strategic way of attributing meaning to curriculum contents and, as a result, of bridging the gap between the knowledge taught at school and students' lived experiences (Brasil, 2002).

Nunes (2017) defines contextualization as bringing historical, environmental, and social aspects of scientific knowledge to the classroom. In the teaching of chemistry, contextualization occurs when students are exposed to situations through which they can confer meaning to this branch of knowledge and see its relevance to their daily lives (Oliveira et al., 2020; Tavares et al., 2021). Contextualization and interdisciplinarity (i.e., encompassing several branches of knowledge) are considered important pillars of the National Curriculum Parameters for Secondary Education (PCN+) (Brazil, 1999; Cavaglier & Messeder, 2014).

The PCN+ assign the topic “Astronomy” to the teaching of physics, within the structuring axis “Universe, Earth, and Life,” while recognizing that this topic encompasses other branches of knowledge, such as mathematics, chemistry, geography, and biology (Brasil, 2002). As very little or no astronomy content is taught at schools (Langhi & Nardi, 2012), this topic could be very well assigned to the teaching of chemistry, given that this branch of science is also part of the study of astronomy, e.g., the chemistry of the universe or, specifically, the chemistry of the solar system.

In addition to being ubiquitous in everyday life, chemistry can go beyond it; it can reach places that have not yet been visited by human beings, as is the case of other planets and their satellites in the solar system. For instance, hydrogen and

helium predominate in the sun and the nucleus of Mercury is mostly made up of iron, whereas Venus, Earth, and Mars consist of $\frac{1}{3}$ metals and $\frac{2}{3}$ silicates (Lazzaro, 2009).

Learning science can be made more accessible and interesting when its contents are associated to real-world examples (Trevisan & Lattari, 2003). Furthermore, the teaching of astronomy can, according to Dias and Rita (2008), promote student awareness of nature as a dynamic process and foster a historical understanding of scientific progress.

Ludic teaching materials, such as instructional guidebooks, can facilitate teaching when they are employed to mediate teacher-student and student-student discussions (Marteis et al., 2011; Moraes et al., 2015). Instructional guidebooks are a means of communication in which the curriculum subject matters they cover mirror real-world situations and phenomena (Collares, 2011). They allow the teaching of any given subject matter in a condensed, didactic, illustrated, and accessible way to diverse student audiences (Baia, 2018).

For Zombini and Pelicioni (2011), the development of teaching materials involves an in-depth search for scientific knowledge in specialized books and journals, i.e., relevant information in order to be able to devise a teaching approach that is at the same time interesting, accessible, and meaningful to the particular student audience at hand.

In this vein, it is vital that chemistry teachers facilitate student understanding of curriculum contents by approaching them from different angles. Interdisciplinary teaching models involving chemistry and astrology are thought to be capable of drawing student interest and curiosity, thus favoring different ways of thinking about the natural world and of explaining it. The use of illustrated texts makes contents easier to understand and, thus, is believed to contribute to student learning — especially among children and adolescents — of more abstract curriculum subject matters, such as astronomy. For that reason, this resource can be important to the teaching of chemistry.

According to Rama et al. (2014), the combined use of text and images in instructional guidebooks can improve student understanding of concepts and theories, which would be more difficult to accomplish if taught otherwise. The use of images and illustrations is important in that they shed light on real-world situations and favor student perception of details (Bacelar et al., 2009). Along these lines, this study aimed at drawing the participating students' interest in chemistry in conjunction with astronomy, an appealing topic to most of them.

Thus, this interdisciplinary approach to the teaching of chemistry — addressing basic knowledge of reactions occurring in the solar system — is hypothesized as capable of promoting student learning of secondary-level chemistry concepts and theories. In addition, it is assumed that the use of an instructional guidebook on the aforementioned topic is capable of supporting the teaching and learning process in this time of pandemic and social distancing.

In this context, it is important to devise alternative teaching methods and resources, such as virtual classes and instructional guidebooks, to assist teachers and students in reaching their instructional objectives in a contextualized and interdisciplinary way. It is also important to combine different teaching approaches in line with today's standing of education in order to improve the teaching-learning process and empower students to explore new information and construct new knowledge.

It is expected that this instructional material, i.e., the guidebook, be used as an instructional tool by public school teachers and that it promote more meaningful student learning of chemistry concepts and theories grounded on critical thinking and scientific literacy.

2. Methodology

This case study of a qualitative nature (Yin, 2001) comprised two phases: (1) writing a guidebook and (2) conducting online and face-to-face classes. The study was designed to promote interdisciplinary and contextualized teaching of the

chemistry of the solar system supported by a guidebook written for the occasion. Data was collected by means of two questionnaires (pre-intervention and a post-intervention) and classroom observations.

2.1 Guidebook

Before writing the guidebook, an in-depth bibliographic survey was carried out in science textbooks and journals in order to find information, i.e., secondary-level chemistry concepts and theories, in the context of astronomical phenomena.

The guidebook (Figure 1) was researched for and written in November and December 2021, respectively. Its layout, design, and illustrations were done on Microsoft Word. Images of the planets, satellites, and phenomena are from the websites and webpages cited in the figure captions. The guidebook included concise biographies of scientists of major importance to astronomy, namely, Galileo Galilei, Nicolaus Copernicus, Isaac Newton, Hypatia of Alexandria, and Johannes Kepler. Scientific curios — about scientific discoveries during the course of civilization — and a small puzzle were also interspersed throughout the text. The guidebook in Portuguese and English can be accessed at https://drive.google.com/file/d/1yeq7nCxZ7GowN5qIvQi_w0HSu2eqa20C/view?usp=sharing.

Figure 1 - Some pages from the guidebook.



Source: Authors (2022).

2.2 Implementation of project

Once prepared, the instructional materials were handed to five public secondary schools in Itacoatiara, AM, Brazil. Video lessons, questionnaires (before and after the intervention), and a guidebook were made available to the school where the project was implemented face-to-face. Thirty students participated in the study

Through the application of the questionnaire and the interview protocol, it was possible to identify if the students had previous knowledge about the subject and if they would like to have more contact with this content in chemistry classes. The evaluation questionnaire, in turn, was used in order to verify if the use of contextualization and interdisciplinarity, through the reading of the illustrative booklet, contributed to the teaching-learning process and favored the commitment and interest of students in the discipline of chemistry

Syllabus:

1. Information on the solar system;
2. Main chemical compounds formed at the Big Bang;
3. Nuclear reactions;
 - a. Solar energy production through nuclear fusion reactions;
 - b. Aurora borealis;
4. Chemical composition of planetary atmospheres;
5. Chemical composition of satellite atmospheres;
6. Types of radiation;
7. Conception of atom as wave-particle;
8. Dwarf stars, neutron stars, and black holes.

3. Results and Discussion

The study analysis was based on the participating students' answers to the exploratory and evaluation questionnaires and observation of the intervention, i.e., the implementation of the project. The first questionnaire, responded by 23 students, enabled the authors to learn whether the participating students considered chemistry a difficult subject, had any knowledge of astronomy, and regarded it important to work on topics of this branch of knowledge in the chemistry classroom. On the difficulties related to the discipline of chemistry, in research with a high school class, Trindade et al. (2022) found that even though the chemical discipline is considered interesting, they still point to difficulties in the content.

It seems that virtually all of the participants regarded chemistry as a difficult subject and believed that the use of alternative teaching methods could facilitate learning of this branch of science. Most of the students responded that it would be interesting to work through astronomy content in the chemistry classroom and 83% of them reported that they had never heard of aurora borealis (Table 1).

Table 1 - Student answers to some exploratory questions.

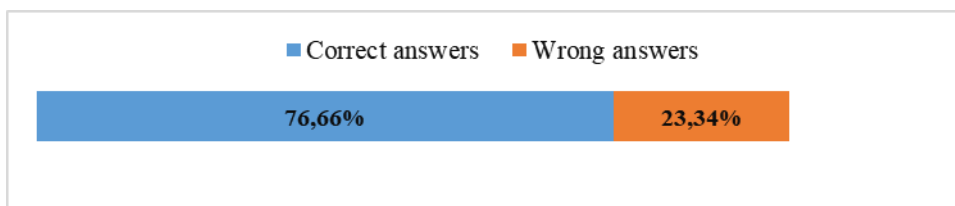
Some Questions from the Exploratory Questionnaire	Some Student Answers
Do you consider chemistry difficult?	“Indeed, it’s very difficult;” “Yes, difficult and complex;” “A little. It involves a lot of calculations;” “Yes, there’s a lot of calculations and formulas;” “It’s a bit laborious. That’s why it’s difficult;” “It’s not a very appealing subject. I believe that’s what makes it more difficult;” “It has too much calculation. I can’t follow it;” “Its problems are too hard to understand;” “I like the teacher, but the course is difficult.”
Have you ever heard of a phenomenon called aurora borealis?	“No, I haven’t;” “No, never;” “A little;” “Yes, I have, but I can’t explain what it is;” “No, not yet.”
Would you be interested in working through astronomy topics in the chemistry classroom?	“Yes, that would be great;” “Yes, it would make it more interesting;” “Yes, absolutely;” “Yes, I’d love to learn more about astronomy;” “It would make it more interesting;” “Lab classes would be nice, too.”

Source: Authors (2022).

The above answers, given by the participating students before the intervention, indicate that they were receptive to new teaching methods, which encouraged the authors to write the guidebook and plan and implement the project. Once implemented, it was possible to observe the participants’ active involvement in class and interest in the guidebook. The teaching-learning process became more ludic and enjoyable because the instructional material allowed for a different approach to scientific matters through a more straightforward and accessible language (Santos, 2019).

At the end of the intervention and use of the guidebook, the participating students responded to an evaluation questionnaire focusing on their learning of the subject matter in question. The first question (Q1) “There are eight planets and two categories of planets in the solar system. What are their names and how are they categorized?” was answered correctly by 23 out of 30 respondents (77%) (Figure 2).

Figura 2 - Analysis of Q1 of evaluation questionnaire.

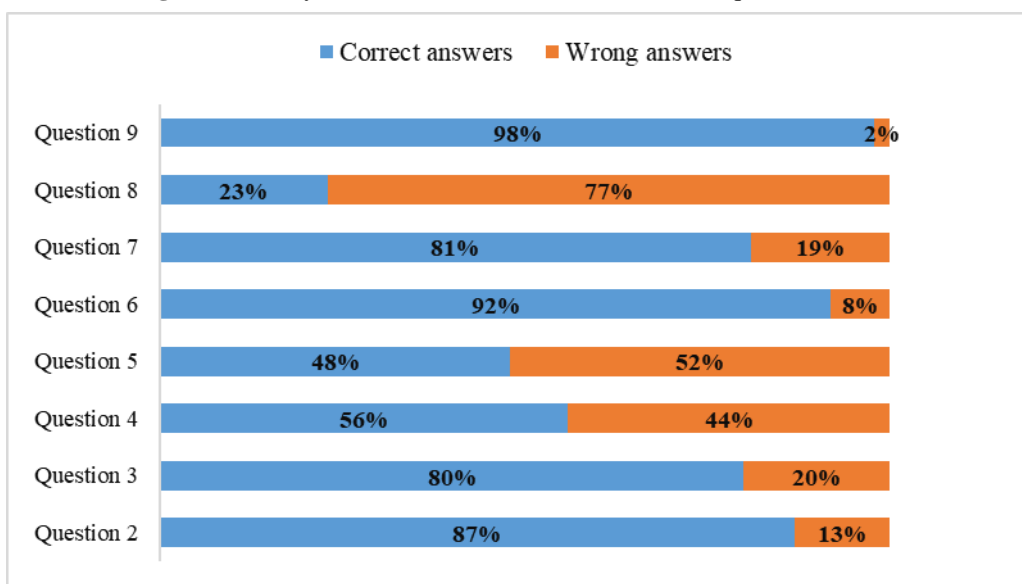


Source: Authors (2022).

The remaining questions on the evaluation questionnaire were (Q2) What are the main atmosphere components of the gaseous planets, (Q3) Where is sulfuric acid found in Venus?, (Q4) What is a nuclear fusion reaction, (Q5) What is a nuclear fission reaction?, (Q6) What is the sun mostly made of?, (Q7) Which planets do not have natural satellites?, and (Q9) Which planet has the greatest number of satellites?

The percentages of right and wrong answers to Q2-Q9 are shown in Figure 3. In average, 71% of the participants gave correct answers to the questions. Given that most students had not been exposed to chemistry theories and concepts in the context of astronomy before the intervention, the results indicate that the use of the guidebook in class promoted their understanding of the subject matter at hand.

Figure 3 - Analysis of answers to Q2-Q9 of evaluation questionnaire.



Source: Authors (2022).

The student answers to the evaluation questionnaire and classroom observations indicate that the guidebook worked as a facilitation tool (Senna et al., 2006) and, thus, contributed to the teaching-learning process by providing the participating students with opportunities to think about the chemical components of the sun, planets, and satellites in addition to fostering student learning of chemistry concepts. The use of the guidebook also fostered teacher-student and student-student interactions as well as student interaction with the instructional materials in the classroom. It also made teaching and learning more enjoyable and interesting.

Moreover, the results suggest that the instructional tool, i.e., the guidebook, promoted student learning and acquisition of new knowledge. The chosen topic, i.e., the chemistry of the solar system, was highly motivating to the participants. Indeed, astronomy seems to appeal to most students, but its topics are seldom discussed or worked through in the classroom in spite of its presence in the PCN+ (National Curriculum Parameters for Secondary Education) (Langhi & Nardi, 2009).

4. Final Considerations

The project of writing a guidebook on astronomy, focusing on the chemistry of the solar system, with which to promote student learning of chemistry concepts and theories showed the importance of making use of teaching tools that facilitate learning as they can bridge the gap between the classroom on the one hand and on the other, real-world science and students' daily lives. This study also suggests that contextualizing theories and concepts, by demonstrating to students the ubiquity and relevance of chemistry — and science for that matter — to their everyday lives and society at large, is an effective means of motivating their learning of this important branch of knowledge.

Through this work, it is expected that other teachers can use this theme of astronomy for the teaching of chemistry, in addition to using this guidebook, which is an easy-to-read and understandable material, for reading in the classroom in order to stimulate and assist in the student learning process in chemistry classes.

References

Bacelar, B. M., Pinheiro, T. S. de M., Leal, M. F., Paz, Y. M., Lima, A. S. de., Albuquerque, C. G. de., Corrêa, M. M., Cordeiro, I., Silva, V. L., & Eldeir, S. (2009). Metodologia para elaboração de cartilhas em projetos de educação ambiental em micro e pequenas empresas. In: *IX Jornada de Ensino, Pesquisa e Extensão*. Anais [...] IX Jornada de Ensino, Pesquisa e Extensão.

- Baia, J. D. (2018). *Desenvolvimento e validação de uma cartilha educativa sobre a doença periodontal em cães e gatos*. Dissertação (Mestrado em Clínica Cirúrgica Veterinária) – Universidade de São Paulo. Faculdade de Medicina Veterinária e Zootecnia., São Paulo. <[http://www.teses.usp.br/teses/disponiveis/10/10137/tde-18102018-154132/ptbr.php#?>](http://www.teses.usp.br/teses/disponiveis/10/10137/tde-18102018-154132/ptbr.php#?).
- Brasil. (1999). Ministério da Educação, Secretaria de Educação Média e Tecnológica (SEMTEC). *Parâmetros Curriculares Nacionais: ensino médio*–Brasília: Ministério da Educação.
- Brasil. (2002) Ministério da Educação (MEC) - Secretaria de Educação Média e tecnologia (Semtec). *PCN+ Ensino médio: orientações educacionais complementares aos Parâmetros Curriculares Nacionais – Ciências da Natureza, Matemática e suas Tecnologias*. Brasília: MEC/SEMTEC, p.93.
- Cavaglier, M. C. dos S., & Messeder, J. C. (2014). Plantas Medicinais no Ensino de Química e Biologia: Propostas Interdisciplinares na Educação de Jovens e Adultos. *Revista Brasileira De Pesquisa Em Educação Em Ciências*, 14(1), 055–071. <https://periodicos.ufmg.br/index.php/rbpec/article/view/4282>
- Collares, S. A. O. (2011). O uso da cartilha progressiva (1907) nas escolas do estado do Paraná. In: *XXVI Simpósio Nacional de História* – ANPUH. São Paulo.
- Dias, C. A. C. M., & Rita, J. R. S. (2008). Inserção de Astronomia como disciplina curricular no Ensino Médio. *Revista Latino-Americana de Educação em Astronomia*, 6, 55-65.
- Kato, D. S., & Kawasaki, C. S. (2011). As concepções de contextualização do ensino em documentos curriculares oficiais e de professores de ciências. *Ciência & Educação*, 17 (1), 35-50. <https://doi.org/10.1590/S1516-73132011000100003>
- Langhi, R., & Nardi, R. (2009). *Ensino de Astronomia no Brasil: educação formal, não formal e divulgação científica*. *Revista Brasileira de Ensino de Física*, Florianópolis, 31 (4).
- Langhi, R., & Nardi, R. (2012). *Educação em Astronomia: Repensando a formação de professores: Escrituras*.
- Lazzaro, D. (2009). *Astrofísica do Sistema Solar*. http://www.on.br/site_edu_dist_2009/site/modulos/modulo_1/1-introducao/1-introducao.html
- Marteis, L. R., Makowski, L. S., & Santos, R. L. C. (2011). Abordagem sobre dengue na educação básica em Sergipe: análise de cartilhas educativas. *Scientia Plena*, 7 (6), 069901.
- Moraes, S. Z. C. (2015). *Plantas medicinais: sua abordagem em livros de ciências do ensino fundamental*. Monografia (Graduação em Ciências Biológicas) – Departamento de Biologia, Universidade Federal de Sergipe. São Cristóvão – SE.
- Nunes, P. P. (2017). *Contextualização e abordagem de conceitos químicos por meio da química forense: uma sequência didática para o Ensino Médio no Ensino da Química*. 140 f. Dissertação (Mestrado em Ensino de Ciências e Matemática) - Universidade Federal do Amazonas, Manaus.
- Oliveira, L., Santos, M., Franco, L. G., & Justi, R. (2020). Contextualização no Ensino de Química: conexões estabelecidas por um professor ao discutir uma questão do enem em sala de aula. *Ciência & Educação*, Bauru, 26, 1-17. <http://dx.doi.org/10.1590/1516-731320200062>.
- Rama, A., Vergueiro, W., Barbosa, A., Ramos, P., & Vilela, T. (2014). *Como usar as histórias em quadrinhos na sala de aula*. São Paulo: Contexto.
- Santos, L. P. dos. (2019). *Elaboração e utilização de uma cartilha como ferramenta didática no ensino da Botânica para o nível médio*. Trabalho de Conclusão de Curso (Licenciatura em Ciências Biológicas) – UFPE/Vitória de Santo Antão, Pernambuco.
- Senna, S. N., Silva, M. V., & Vieira, M. R. (2006). Uso de cartilha com atividades lúdicas como material complementar para o ensino e aprendizagem de doenças parasitárias. In: *ENCIVI - Encontro das Ciências da vida*, 6, Ilha Solteira, SP. Anais [...] Ilha Solteira: UNESP.
- Tavares, N. S., Carneiro, K. de A. A., Santos, M. B. H. dos, Silva, R. F., Nascimento, R. J. de A., Diniz Júnior, A. I., & Silva, T. P. da. (2021). Análise da percepção de estudantes do Ensino Médio acerca do processo de aprendizagem em Química. *Research, Society And Development*, 10 (2), 1-16. <http://dx.doi.org/10.33448/rsd-v10i2.12774>.
- Trevisan, R. H., & Lattari, C. J. B. (2003). Investigando a aprendizagem de astronomia no ensino fundamental, usando um método experimental. In: *Atas do IV Encontro nacional de pesquisa em educação em ciências*, Bauru.
- Trindade, Í. T. M., Lopes, A. da S. N., Cárdenas, A. G., Ramos, A. R., Souza, C. M. de, Soares, S. T., Silva, V. H. N., Corrêa, G. M., Menezes, J. M. dos S., & Carmo, D. F. de M. do. (2022). Virtual Chemistry Laboratory: a didactic alternative to the teaching of Organic Chemistry. *Research, Society and Development*, 11 (10), e426111032888. [10.33448/rsd-v11i10.32888](https://doi.org/10.33448/rsd-v11i10.32888).
- Yin, R. K. (2001). *Estudo de caso: Artmed*.
- Zombini, E. V., & Pelicioni, M. C. F. (2011). Estratégias para a avaliação de um material educativo em saúde ocular. *Revista Brasileira de Crescimento e Desenvolvimento Humano*, São Paulo, 21(1), 51-58. <http://dx.doi.org/10.7322/jhgd.19995>.